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When open source design is vital: critical making of DIY healthcare equipment during the COVID-19 pandemic

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ABSTRACT

Shortages of personal protective equipment (PPE) and medical devices needed during the COVID-19 pandemic were widely reported in early 2020. In response, civic DIY volunteers explored how they could produce the required equipment. Members of communities such as hacker- and makerspaces employed their skills and tools to manufacture, for example, face shields and masks. The article discusses these civic innovation practices and their broader social implications by relating them to critical making theory. Methodologically, it is based on a digital ethnography approach, focusing on hacker and maker communities in the UK. Communities' DIY initiatives display characteristics of critical making and 'craftivism', as they assessed and counteracted politicised healthcare supply shortages. It is argued that their manufacturing activities during the COVID pandemic relate to UK austerity politics' effects on healthcare and government failure to ensure medical crisis supplies. Facilitated by open source design, communities' innovation enabled healthcare emergency equipment. At the same time, their DIY manufacturing raises practical as well as ethical issues concerning, among other things, efficacy and safety of use.

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Introduction

In early March 2020, the *World Health Organization* (WHO) red-flagged shortages of personal protective equipment (PPE) that were needed to prevent the spreading of coronavirus. A lack of PPE, the WHO warned, was compromising the working conditions and endangering the health of medical professionals worldwide. Similar shortages were feared for devices, such as ventilators, crucial for the intensive care treatment of COVID-19 patients.

While governments called upon commercial manufacturers to start producing the required equipment, civic innovators were largely overlooked. And yet, relevant grassroots initiatives were emerging. For example, Italian volunteers 3D-printed lifesaving respiratory valves when a hospital in Brescia found its supply chain exhausted. Also in Germany, the Netherlands, Spain, the UK, and elsewhere in the Global North and South, DIY (Do-it-

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yourself) communities employed their skills and tools: members of hacker- and makerspaces produced, among other things, face shields, surgical masks, and respirators.

The terms 'hacker' and 'hacking' tend to be associated with cybercrime (Jordan, 2017). This is regrettable because hacker-/hackspaces are resourceful, legal civic communities of skilled technology and crafts enthusiasts – just like makerspaces. Members of such communities engage in DIY practices: to do so, they usually frequent dedicated, physical community spaces, with access to shared (digital) machines and (craft) tools. Some communities also use public spaces such as libraries. While meeting physically, members exchange information and discuss issues via e.g. mailing-lists, forums, and communication platforms like Slack or IRC. In this article I highlight how UK hacker and maker communities responded to shortages of healthcare equipment during the COVID pandemic in early 2020. These communities discussed, developed, and rapidly produced supplies needed by healthcare professionals and key workers. To do so, they drew on open source hardware design and manufactured devices using tools such as laser cutters, 3D-printers, and sewing machines.

I certainly do not argue for DIY medical equipment as a long-term solution for shortages. Volunteers' efforts can add to, though not replace, large-scale manufacturing. And obviously, avoiding any lack of healthcare equipment in the first place should have priority. However, I suggest that we can learn important lessons from these civic responses by reflecting on the broader social implications of emergency DIY medical equipment.

Drawing on critical making theory (Ratto, 2011; see also Hertz, 2012; Kohtala, 2017) in relation to civic innovation (Biekart et al., 2016; Girouard & Sirianni, 2014), I show that hacker- and makerspaces can make vital contributions during times of crisis. The healthcare projects initiated during the pandemic illustrate how DIY communities critically assessed and productively responded to societal issues. I argue that their activities relate to UK politics of healthcare funding and government failure to ensure medical emergency supplies. More than a decade of austerity, with effects on public health being particularly noticeable since 2013, has impaired the UK's preparedness and capacity to counteract the COVID pandemic.

While communities' activities speak to the potential of civic innovation, they are likewise symptomatic of systemic issues necessitating civic groups to step in. In this sense, their DIY practices may not be overtly political in a 'party-political sense', yet they counteracted healthcare supply shortages that were, as such, politicised. Moreover, socio-technically, they speak to the benefits of open source design (see also Chagas, Molloy, Prieto-Godino, & Baden, 2020; Kohtala, 2020). Open source approaches enabled communities to collaboratively improve and to co-produce their projects in consultation with public health professionals.

Having been much appreciated in the UK and elsewhere, DIY medical equipment also raises practical and ethical challenges concerning distribution, efficacy, and safety of use. If volunteers make equipment, will healthcare professionals be able to use it? What kind of standards need to be upheld and who is (and feels) responsible for the equipment's efficacy and safety? Such issues have been critically assessed by members of hacker-/makerspaces too. In terms of critical making theory related discussions show that volunteers' efforts combined 'two modes of engagement with the world that are often held separate – critical thinking, typically understood as conceptually and linguistically based, and physical "making", goal-based material work' (Ratto, 2011, p. 253). Before starting the production,

they assessed requirements of key (healthcare) workers and gained a better understanding of standards to ensure that DIY equipment may be used.

To develop the above arguments, I will first elaborate on civic innovation and relate it to critical making theory. I will then explain my focus on the UK and my digital ethnography approach. The analysis of UK communities' efforts in medical equipment manufacturing focuses on two main aspects: first, treating their civic innovation practices as critical making, I reflect on their broader social implications and highlight the relevance of open source design; second, I explore some of the practical and ethical challenges that arise from emergency DIY medical equipment.

Theory and societal implications

Conceptually, this article draws on critical making theory in relation to civic innovation. Civic(-driven) innovation implies an involvement of citizens in leading roles and allows for their agency in developing/implementing new ideas (Biekart et al., 2016, p. 5). Science and technology studies scholars, among others, have pointed out that there is rarely a 'straightforward progression from scientific research (knowledge production) to innovation (its application into new technologies)' (Mormina, 2019). This is even more the case when it comes to civic innovation, as projects are not necessarily driven or supported by economic incentives (see also Girouard & Sirianni, 2014). Instead, civic innovation refers 'to creative forms of cultural political and economic resistance and pathways to social change' (Biekart et al., 2016, p. 5).

I argue that the civic innovation of UK hacker-/makerspaces during the COVID pandemic displays characteristics of 'critical making'. Ratto (2011) originally developed this notion 'within the social study of technology' (p. 252), to analyse reflective prototyping which explicitly connects 'to specific scholarly literature' (p. 253). Meanwhile, the concept has also been applied to civic and communal maker practices starting from societal issues (Criado, Rodríguez-Giralt, & Mencaroni, 2016; Hertz, 2012; Kohtala, 2017). Rather than understanding DIY activities mainly as means for personal, creative fulfilment and enjoyment, critical making stresses their potential for learning and their societal relevance.

Critical making theory is closely linked to civic possibilities for activism through craft and technology engagement (Mann et al., 2014). Orton-Johnson (2014) relates critical DIY practices to 'craftivism' and conceptualises such activism through crafts as 'socially engaged and socially networked DIY citizenship' (p. 142). It appears therefore insightful to analyse hackers' and makers' DIY production of healthcare equipment in terms of critical making and crafts-driven activism too. Volunteers critically assessed and responded to equipment shortages that were politically charged, since they resulted from government failure to ensure healthcare supplies. They grappled with DIY possibilities and limitations for producing required equipment, specifically with regards to issues of maintaining medical/healthcare standards.

Focus and approach

While the increased need for PPE appeared at the latest by early February, the UK missed several opportunities for obtaining required equipment. Among other things, it did not participate in the joint EU procurement of equipment such as masks, goggles, and

gowns. By mid-April, amidst government officials still downplaying the lack of PPE (Siddique, 2020), medical professionals in hospitals were asked to wear aprons instead of full-length protective gowns. Already prior to this, primary care staff had voiced concern about being required to see potential COVID patients wearing face masks (rather than respirators), one pair of gloves, and a disposable apron (Greenhalgh, 2020).

Healthcare workers in the UK had for a while sounded the alarm over the shortages when hospital managers resorted to going public. Without appropriate protective equipment, the safety of staff could not be guaranteed. The UK is thus one of the countries, comparable to the US, where healthcare workers experienced a critical, widespread lack of PPE. These issues also need to be seen in the context of the UK's public healthcare system, the National Health Services (NHS). In the context of more than a decade of (recent) austerity, the NHS has been under longstanding financial pressure and suffers from staff shortages. Due to the severity of PPE/equipment shortages and a seriously strained healthcare system, it is relevant to look at civic technology responses in the UK. That said, the UK is neither the only state to experience PPE shortages nor the only one where civic communities stepped up.

At this time, I was already working on a research project on learning practices among UK hacker and maker communities when the COVID crisis began unfolding. For my project, I am conducting a digital ethnography (Hjorth, Horst, Galloway, & Bell, 2017). Ethics approval for this project was provided by the University of Sussex Social Sciences and Arts Cross-school Research Ethics Committee.

My research is based on those groups that are part of the UK *Hackspace Foundation* (https://www.hackspace.org.uk). I am subscribed to mailing-lists, read and comment on forums, and participate in communication via platforms such as Discourse, Slack or Twitter. On these platforms, from mid-March 2020, I encountered a surge of conversations concerning PPE shortages and what could be done about that using communal skills and tools.

While hacker-/makerspaces closed their doors once the UK government announced the countrywide lockdown on 23 March 2020, some communities allowed access for those who were working on PPE and other medical equipment. I have not participated in any manufacturing of PPE myself and have instead followed the documentation of these activities online. My fieldwork typically comprises interviews and physical participant observation too, yet the following sections are solely based on virtual observations and conversations.

DIY medical equipment and critical making with open source design

In early March 2020, upon reading about, hearing from, and talking to healthcare workers who feared or experienced PPE, shortages, members of hacker- and makerspaces started exploring possibilities for manufacturing equipment. They launched initiatives to produce face shields/visors and masks. They also examined whether it was sensible to produce devices such as ventilators or ventilator parts, made scrubs and mask strap holders, and built 'aerosol boxes' to be used protectively during the intubation of COVID patients with respiratory failure.

Projects were launched by different communities, among others *DoES-Liverpool*, *Nottingham Hackspace*, *Otley Makerspace*, *Makespace Cambridge*, *South London Makerspace*,

and *The Makers Guild Portsmouth* (an overview of initiatives and online sources is available upon request from the author). These initiatives were closely connected, involving volunteers across communities and exchanging of designs. Typically, websites allowed people to indicate their supply needs, invited other volunteers to sign up, and provided a donation option to help cover the manufacturing costs.

In this section, I analyse communities' practices in terms of critical making. This allows me to highlight their societal relevance and implications for the social study of (open source) technology. At the same time, it contributes to the theoretical field of critical making. On the one hand, treating these projects as critical making contextualises them within broader DIY trends moving beyond personal or communal matters: DIY has become a 'craftivist' (Orton-Johnson, 2014) means of responding to and exposing issues of political, societal, and environmental relevance (Kohtala, 2017). In producing medical emergency equipment, communities ignored initial claims by UK government officials that there were no PPE shortages to be concerned about. Instead, they directly coordinated their work with affected healthcare professionals. In confirming the supply needs of hospitals and primary care providers and making their projects public, they exposed the fact that PPE and other equipment were indeed much needed. Hence, their efforts were inextricably linked with contemporary UK politics of insufficient healthcare funding and government failure to ensure emergency equipment supplies during the COVID crisis.

On the other hand, hackers'/makers' projects also point to aspects of critical making that would deserve even more attention in sociological research: critical making for matters of healthcare. In times of mounting global crises and public funding cuts, DIY communities are seeking to make up for systemic issues causing healthcare shortcomings. In their study on critical making and DIY healthcare design, Criado et al. (2016) explore how Spanish communities respond to the ongoing crisis of care and austerity by devising alternative, disability-oriented products and services. O'Kane's work on DIY health and wellbeing shows how maker communities contribute technological solutions for individuals suffering from, for example, Type-1-Diabetes. Such practices need to be seen in the context of a broader trend observed in health sociology: Iedema and Veljanova, among others, point out the emergence of an 'anti-establishment science movement' exploring possibilities for 'co-produced care and do-it-yourself healing' (2013, p. 2; see also Bergschöld, Neven, & Peine, 2020).

UK volunteers' manufacturing of DIY healthcare equipment starts from the insights that government emergency supply efforts are insufficient and that much needed equipment will be delivered too late. Their approaches differ from earlier notions of critical making, for which the product mattered less than the process, and manifest forms of critical making grounded in civic innovation. Ratto (2011) envisioned critical making as a way of 'furthering critical knowledge through joint material production' (p. 252). The critical, communal DIY practices observed in my study and elsewhere indicate that they indeed required individuals to gain knowledge to produce certain objects. In addition, the production of such objects was not mainly a matter of learning and understanding, but of creating material contributions to tackle societal issues.

Socio-technically, as Criado et al. (2016) observe, values of openness, collaboration, and co-production are crucial for critical making dynamics. Also Iedema and Veljanova (2013) emphasise the relevance of 'alternative forums of social engagement such as

provided by open source technology where contemporary individuals negotiate and share their everyday care experiences' (p. 2). Open source design, communal cooperation, and co-production were indispensable for the DIY emergency equipment manufacturing. For example, in consultation with a local anaesthetist, a *Richmond MakerLabs* member made an 'aerosol box'. The device had been previously developed by a medic in Taiwan, in response to PPE shortages, and published under a Creative Commons non-proprietary license. In the case of masks, volunteers provided sewing patterns and shared their instructions via social media. Face shields were developed by drawing on previous open-source designs and the adjusted files were publicly shared. *The Makespace Cambridge*, for example, developed a visor design that the community published using a CC-license. Their work, in turn, was based on open-source face shield instructions by *Delve/Midwest Prototyping* and the *University of Wisconsin-Madison Makerspace*. This synergy of open source design, use, adjustment, and hardware production was characteristic of communities' activities responding to the COVID pandemic.

The relevance of open source for critical making has been highlighted previously (see Criado et al., 2016; Kohtala, 2017; O'Kane, 2016) – but it seems that it cannot be stressed often enough. Medical manufacturers, among others, still argue that patents are indispensable for incentivising research and innovation, thus improving healthcare. However, DIY activism during the coronavirus pandemic calls this assumption into question (see also Gold, Kaplan, Orbinski, & Harland-Logan, 2010). UK communities' DIY projects reemphasise the strengths of open design approaches. They illustrate that open source design fuels civic innovation. It has been vital in enabling communities to produce and distribute healthcare emergency solutions.

Communities' DIY projects were thus 'critical' in several ways: first, they assessed, responded to, and further exposed politicised healthcare equipment shortages. Second, in drawing on open source design and collaborative manufacturing approaches, they countered proprietary, profit-driven healthcare innovation. They opposed these with civic innovation, resisting government narratives of sufficient PPE supplies and mobilised volunteers to tackle shortages with the help of open design approaches. The latter also matters in tech-political terms, as communities' activities illustrate that civic innovation – while certainly in need of funding – do not require proprietary approaches and would be thwarted by approaches preventing an exchange of designs.

If we make it, can they take it?

In addition to being critical in their material-political resistance and open source approaches, hackers and makers faced practical as well as ethical challenges. Apart from practical matters of financing, sourcing of material, distribution, and assessing supply needs, volunteers discussed which requirements and medical standards needed to be considered.

Medical equipment in the UK is subject to standards and regulations overseen by The Medicines and Healthcare Products Regulatory Agency. The government provided for exceptions from device regulations during the COVID crisis but was still asking for fast-tracked reviews. Hence communities faced the dilemma of having to decide whether to produce and directly distribute equipment that they knew was needed but

strictly regulated. Many communities decided to bear the risk, often responding to requests from healthcare workers.

Masks and face shields were favoured choices for DIY projects. Face shields had been explicitly requested by medical staff and were considered likely to be accepted, even in clinical settings. In primary care, they would add a safety level rather than replacing provided PPE. Textile masks were widely needed in hospitals as well as other healthcare settings. Thus, even if medical standards for surgical masks could not be upheld, these would be beneficial to non-medical key workers.

Most communities abandoned attempts at producing devices such as ventilators needed during the intensive care treatment of COVID patients. Their clinical approval was considered crucial, from a practical and ethical perspective. Volunteers considered the approval neither likely to be gained, thus their efforts may we misspent, nor neglectable: even if ventilators were needed, the risk of malfunctioning and volunteers' (moral) responsibility were deemed serious. Communities' reflective practices again echo aspects of critical making, in that they connected a discursive engagement with societal challenges and crafts-/technology-driven activities. They assessed and validated societal issues, i.e. PPE and other medical device shortages, before moving on to how this issue may be tackled through material manufacturing.

In a commentary on global DIY maker efforts during the COVID crisis, Kohtala (2020) points out that:

> The global maker communities' response to provide locally fabricated medical equipment to front-line workers has been extremely fast-moving […]. Open design files have been shared and modified, but because of the flurry of action not everyone has known what to do; there has simply been a surge of enthusiasm and a rush to printers.

While a critical assessment of communities' practices is certainly in order, the described enthusiastic and autonomous communal ethos also played a key role in making hackers/makers flexible emergency responders. Moreover, UK communities appeared aware of challenges related to medical standards/requirements (though there may well be exceptions). Such issues were discussed, also involving healthcare workers. This led to decisions against producing certain items, such as ventilators.

Hence, communities' discussions can be related to critical making as means for gaining a better understanding of societal and socio-technical issues too. In their paper on DIY prosthetics workshops, Record et al. (2013) stress that critical making has the potential to link 'conceptual and material exploration […] increasing understanding and developing critical insights' (p. 118). The authors describe how making DIY prosthetics allows individuals to gain empathic insights into the needs of those requiring the devices. Similarly, the decision to produce PPE and other equipment led hackers and makers to delve into the specifics of medical equipment requirement and healthcare/key workers' needs.

Having said that, Kohtala (2020) is right in advising caution. By entering the domain of healthcare equipment, hackers' and makers' practices raise safety questions and ethical issues. These concern volunteers' safety, i.e. during their manufacturing efforts, but are also relevant to healthcare staff resorting to the use of DIY equipment. Healthcare staff may need to assess DIY devices locally – adding another layer of responsibility to their tasks and raising further questions of required expertise for such an assessment. DIY equipment also exposes them to various dilemmas: Equipment may suggest safety

without having been checked for efficacy; and the availability of DIY equipment may put pressure on staff to use such devices and continue their work despite concerns. While I am unable to map out these issues in detail in this short paper, it can already be concluded that one needs to consider that DIY medical equipment allows for emergency solutions, but likewise raises issues concerning how its safety and efficacy may be safeguarded.

Conclusion

This article highlights the social relevance and implications of civic healthcare innovation created in hacker-/makerspaces. It speaks to the benefits of open source approaches for healthcare emergency supplies. During the COVID pandemic in early 2020, UK hacker and maker communities manufactured PPE and other healthcare equipment. They responded to shortages that were widely reported yet initially denied by UK government officials. I conceptualised volunteers' DIY manufacturing of healthcare equipment as critical making (Criado et al., 2016; Kohtala, 2017; Ratto, 2011), as it presupposes a reflective engagement with politized PPE shortages and healthcare equipment requirements of key workers. Analysing communities' initiatives in terms of critical making contributes to this theoretical field by highlighting DIY healthcare technology as a yet little researched domain – while connecting that domain to wider societal issues of UK healthcare politics and funding.

By validating equipment shortages in consultation with healthcare professionals and producing other emergency supplies, I argue that hacker-/makerspaces' activities are inextricably linked to austerity politics and the UK's strained healthcare system. The fact that DIY equipment was needed, exposes government failure to ensure sufficient medical supplies during the COVID crisis in early 2020. While communities' DIY practices may not be overtly political in a 'party-political sense', they counteracted healthcare supply shortages that were politicised. As they did not merely point out, but also tackled, these shortages, their initiatives display 'craftivist' (Orton-Johnson, 2014) characteristics, amounting to crafts- and tech-facilitated activism.

In their critical making, the communities explored means for civic innovation (Biekart et al., 2016) responding and contributing to societal challenges. Open source design played a vital role in this: it allowed communities to co-produce equipment, also in consultation with medical professionals, thus strengthening and accelerating development processes. Medical manufacturers, among others, still argue that patents are indispensable for incentivising public health-related research and innovation. However, hackers' and makers' innovations call this longstanding claim further into question (see also Gold et al., 2010). DIY manufacturing during the COVID pandemic illustrates that open source design fuelled civic innovation (see also Chagas et al., 2020). It has been quite literally vital in enabling communities to produce and distribute healthcare emergency solutions.

Regrettably, policymakers have so far overlooked (or ignored) communities' potential. When the UK government called upon enterprises to switch production to PPE, no consideration was given to communal manufacturing. This did not deter hacker-/makerspaces from stepping in. Still, they neither received any (financial) government assistance for their manufacturing – which partly made up for equipment that would have been paid for through taxes. Instead, the communities had to call upon the public, relied on sponsors and communal funds, to finance their manufacturing.

At the same time, communities' DIY manufacturing came along with practical and ethical issues, potentially affecting volunteers producing and healthcare/key workers using the DIY equipment alike. Not all DIY solutions adhered to medical standards and regulations, thus casting doubt on their efficacy and safety of use in clinical settings. Upon entering the healthcare domain, DIY manufacturing raises challenges for ensuring that equipment may be safely used and does not create an additional burden for healthcare staff.

Lastly, the need for DIY medical equipment is a problematic development amid a health crisis – despite hackers' and makers' initiatives impressively demonstrating the potential of civic innovation. While volunteers made a vital contribution, the very existence of their DIY projects is symptomatic of UK austerity politics' effects on healthcare and of government failure to ensure medical emergency supplies.

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